Time-resolved photoluminescence study of isoelectronic In doped GaN films

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We report the results of time-resolved photoluminescence (TRPL) studies on the isoelectronically doped GaN grown by metalorganic vapor phase epitaxially (MOVPE). The effects of In doping on dynamic process of optical transition, such as the dominant I_2 line, series of TRPL measurements were then carried out in this study. For a typical undoped GaN, it is observed that as we changed the cryostat temperature from 300 to 12 K in (Fig. 1), its recombination lifetime decreases monotonously from 68 to 42 ps with the decreasing temperature. On the contrary, the lifetime of In-doped GaN film grown with 2.12 μmol/min TMIn flow rate remains almost the same, independent of the measurement temperature. Similar phenomenon is also occurred in other doped samples. The corresponding decay lifetime at 15, 150, and 300K as a function of TMIn flow rate during the deposition is shown in Fig. 2. It is surprisingly that the recombination lifetime decreases suddenly as the In reactant is added into the reactor and saturates almost at once to its final value, ~ 30 ps, irrelevant to the TMIn flux. It is worth to note that this decay behavior is essentially independent of measurement temperature for all of our In doped samples.

For undoped GaN film considered here, its recombination behavior can be described well by using Shockley-Read-Hall model (SHR). In this model, the SHR recombination lifetime is closely related to its cross section, trap concentration in the epilayer, and thermal velocity of electron at measurement temperature. It will result in a dependence of $T^{1.5}$ of decay lifetime [1,2] and this can explain well the observation in our undoped GaN film as observed in Fig. 1.

It has been reported that the deep recombination center, such as antisites, vacancies, and dislocations in compound semiconductors can be greatly suppressed by isoelectronic doping to improve the film quality [3]. This is also the case for GaN films as confirmed by our recent study [4]. Based on this argument, we may anticipate an increase of I_2 emission lifetime in our In-doped GaN samples. Nonetheless, an adverse effect is observed. When In is doped into the film, the recombination lifetime is not only reduced, but is also independent of temperature and In source supply. From the aspect of temperature independence of recombination lifetime observed here, we might believe that the quantum-dot-like structures may exist in In-doped samples, because the emission properties of quantum dots are essentially insensitive to the temperature due to its zero-dimensional properties [5,6].

In conclusion, we have employed the time-resolved photoluminescence spectroscopy to study the dynamics of exciton in GaN:In. Experimental results indicate that In doping affects dramatically the transition of I_2 line. We believe that when In is doped in GaN, it could induce a quantum-dot-like recombination center that predominates the recombination process and make the recombination lifetime independent of measured temperature.

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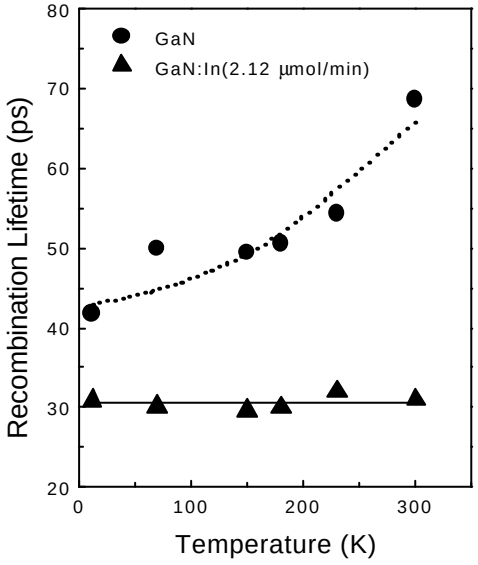

Fig. 1. The recombination lifetimes of undoped and GaN:In (2.12 μmole/min) measured from 12 to 300K. The dotted line presents the curve fitted by $T^{1.5}$ for undoped sample.

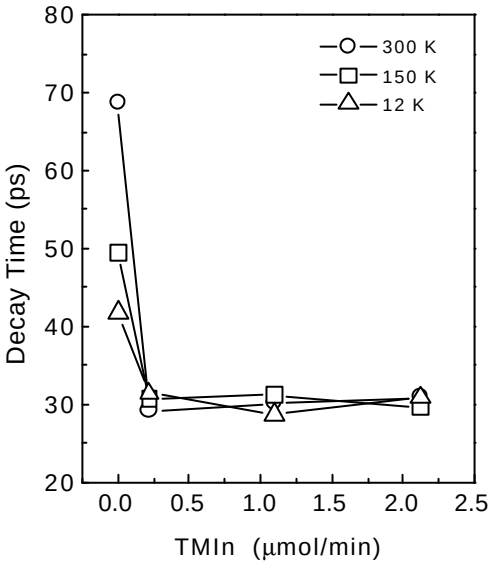

Fig. 2. The recombination lifetimes of doped and undoped GaN films as a function of In source supply measured at 300, 150,and 12 K, respectively.